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Local Measurement Theory for Quantum Cellular Automata

How can genuinely nonlocal quantum measurements emerge from strictly local operations? We address this question within the framework of Quantum Cellular Automata (QCAs), introducing Operational Measurement Protocols: simple procedures that alternate local measurements with the intrinsic time evolution of the system. Remarkably, these protocols reproduce the statistics of nonlocal measurements without requiring any classical communication between distant observers.
Focusing on one dimensional qubit QCAs with nearest neighbour interactions, we explicitly show how entangled measurements can be reconstructed from purely local actions. We also analyze the quantum resources generated in the process, including entanglement and nonclassical features beyond stabilizer physics.
Beyond concrete constructions, our results offer a new operational viewpoint on the local measurement problem in relativistic quantum theories: nonlocal correlations need not arise from global operations or classical post-processing, but can instead be compiled into the causal structure of the dynamics itself. This perspective naturally connects QCAs with quantum computation.

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